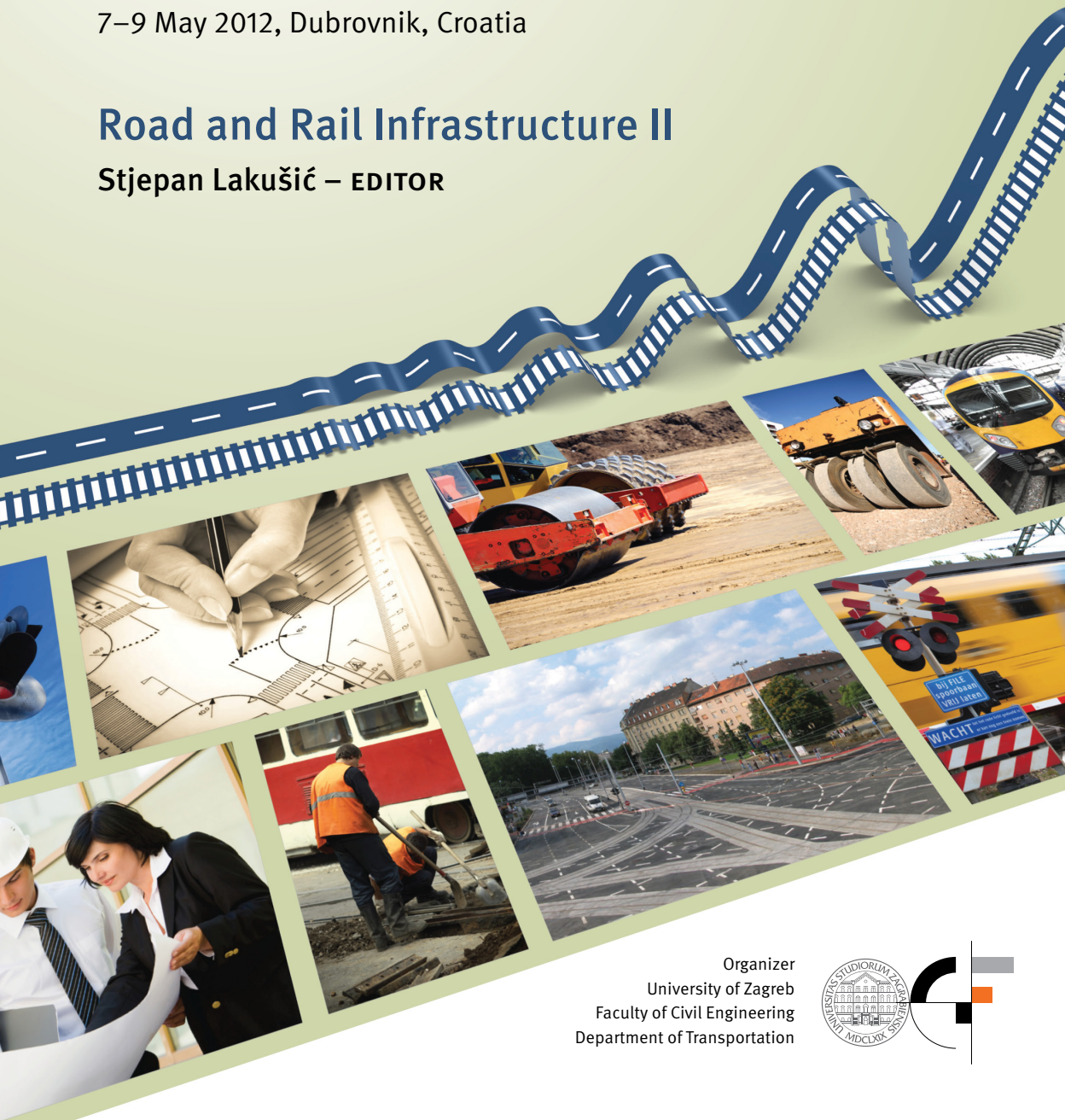
CETRA 2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA2012
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

CETRA 2012
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

ORGANISATION

CHAIRMEN

Prof. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering
Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Maja Ahac
Ivo Haladin
Saša Ahac
Ivica Stančerić
Josipa Domitrović

All members of CETRA 2012 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. Ronald Blab, Vienna University of Technology, Austria
Prof. Vesna Dragčević, University of Zagreb, Croatia
Prof. Nenad Gucunski, Rutgers University, USA
Prof. Željko Korlaet, University of Zagreb, Croatia
Prof. Zoran Krakutovski, University Sts. Cyril and Methodius, Rep. of Macedonia
Prof. Stjepan Lakušić, University of Zagreb, Croatia
Prof. Dirk Lauwers, Ghent University, Belgium
Prof. Giovanni Longo, University of Trieste, Italy
Prof. Janusz Madejski, Silesian University of Technology, Poland
Prof. Jan Mandula, Technical University of Kosice, Slovakia
Prof. Nencho Nenov, University of Transport in Sofia, Bulgaria
Prof. Athanassios Nikolaides, Aristotle University of Thessaloniki, Greece
Prof. Otto Plašek, Brno University of Technology, Czech Republic
Prof. Christos Pyrgidis, Aristotle University of Thessaloniki, Greece
Prof. Carmen Racanel, Technical University of Bucharest, Romania
Prof. Stefano Ricci, University of Rome, Italy
Prof. Tatjana Rukavina, University of Zagreb, Croatia
Prof. Mirjana Tomičić–Torlaković, Univiversity of Belgrade, Serbia
Prof. Brigita Salaiova, Technical University of Kosice, Slovakia
Prof. Peter Veit, Graz University of Technology, Austria
Prof. Marijan Žura, University of Ljubljana, Slovenia

CETRA 2012 7–9 May 2012, Dubrovnik, Croatia
2nd International Conference on Road and Rail Infrastructure

COMPARATIVE ANALYSIS OF ALTERNATIVE FIXED TRACK TECHNOLOGIES FOR THESSALONIKI AIR–LINK CONNECTION

Panagiotis Papaioannou[1], Alexandros Deloukas[2], Ioannis Politis[3], Manos Vougioukas[4]
1 Thessaloniki Public Transport Authority, Greece
2 ATTIKO METRO SA
3 Aristotle University of Thessaloniki, Greece
4 Eurotrans Consulting Ltd, Greece

Abstract

The International Airport of Thessaloniki is the third busiest airport in Greece, serving over 4 million passengers annually. A significant upgrade in terms of capacity is foreseen according to its master plan for year 2030. Expected travellers may reach double figures by then. This increase calls for an improved and more reliable city–airport connection for the future. Three alternatives to the existing bus connection are examined; a further extension of the Metro at–grade which is under construction, a segregated Tramway/LRT, and an elevated Monorail. The new fixed track corridor under consideration will consist of 5 stations and will have a total length of 5.1 kms. The modal operating capacity selected, covers 10 min policy headway, a 25% rail transit share of the total trips and a directed loading of 1,300 passengers per hour per direction (pphpd).
A comprehensive multi modal transport model, developed by Thessaloniki Urban Transport Authority, was used as a supplementary tool, in order to perform extended cost/benefit comparative analysis. The investigation of cost (e.g. operating cost, user cost, rolling stock and infrastructure) and benefit (e.g. time variability risk, novelty image, employment creation) elements, indicate that Monorail is likely to be the least costly and most beneficial rail alternative in a total cost (benefit) perspective. The final decision however depends on both availability of funds and future expansion potential of each alternative.

Keywords: rail technologies, fixed route systems, cost benefit analysis

1 Introduction

The international airport of Thessaloniki 'Macedonia' is the third busiest airport in Greece, serving over 4 million passengers annually. The airport serves local and international flights mainly to European countries and operates on a 24 hour basis. Some 27 scheduled airlines were served in 2011. In addition 21 chartered flights were served during the summer period. 'Macedonia' airport plays a significant role in the network of south–eastern Mediterranean airports and has major future growth prospects, in Eastern Europe, the Balkans and the Black Sea. The airport upgrading works (runway extensions etc.) are in the implementation phase and progress rapidly. In the final phase of operation, the airport will have 2 complete and modern runways and will be able to meet the demand of approximately 8 million passengers per year.
This improvement actually calls for improved and more reliable connections between the airport and the city as well as the surrounding areas. This paper presents the methodology and the results of the comparative examination of three alternatives to the existing bus connec-

tion comprising; a further extension of the Metro at–grade which is under construction, a segregated Tramway/LRT which will start from the Metro terminal station, and an elevated Monorail instead of the Tram/LRT. All alternatives are not only time reliable but also electrified, so their use is air–pollution free and carbon neutral. The rubber–tired technologies investigated are almost free of noise nuisance. The examination took place in the framework of a CIVITAS CATALIST project completed in 2011 [1], [2]

2 Airport and City link Transport and Traffic data

2.1 Airport Transport Data

Thessaloniki airport serves approximately 4 million passengers (arriving and departing) every year. Passenger demand increases significantly during summer months. However intercontinental flights cannot be served due to the short length of the two runways. The extension of runway 10–28, which is under way, will enable intercontinental flights to land and take off from Macedonia' airport increasing in this way significantly the passenger volumes in the future. Air travellers in August which is the heaviest month correspond to 15.4% of annual passengers. Figure 1 left shows the seasonal variation of airport users for years 2009 and 2010 for both regular and chartered flights.

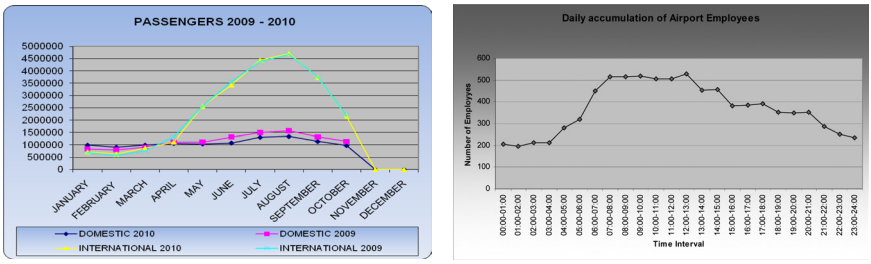


Figure 1 Left: seasonal variation of the different passenger categories; Right: daily accumulation of airport employees

Along with travellers a large number of escorts and airport employees travel to and from the airport. Escorts, according to recent surveys in Athens International Airport [3], account for 10% of air travellers. By taking also into account that for those escorted 1.5 persons in average escort one traveller, it was made possible to estimate number of escort trips. With respect to employees, their number varies between 1125 in winter and 1800 in summer time. During the year some 2,600 commuter trips/day are made from which 75% by car and 25% by PT bus. Figure 1 right presents the daily accumulation of airport employees in a typical day.

2.2 Current Airport Link

Thessaloniki airport is currently linked to Thessaloniki city and the rest of the hinterland only through the existing main highway network. Passengers can access the airport either by private cars and taxis or by public transport (buses). The airport offers three parking facilities able to accommodate up to 1322 vehicles from which 170 for short term parking and the rest for long term parking. Two bus lines serve the airport; the first reaches Thessaloniki city centre and the second a nearby bus–terminal station from where travellers can use other bus lines towards the city centre. The departure frequency is 30 min for each line during winter period and almost doubled during summer periods. A night line also operates all year long. The distance between the airport and Thessaloniki city centre is 14 km and it takes in average 35–45 min by car & taxi and 55–75 min by bus (Figure 2).

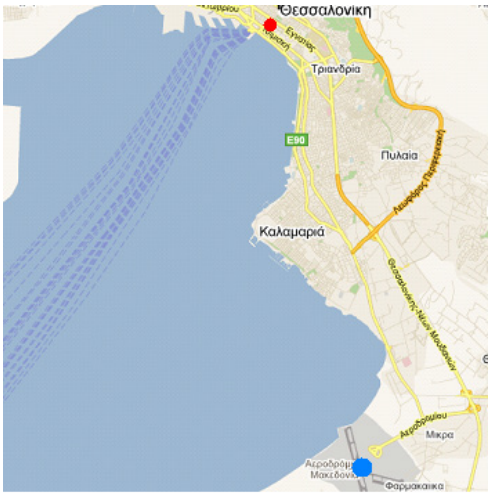


Figure 2 Location of Thessaloniki airport relative to the city

Based on automatic traffic counts, detailed private car and bus passenger counts during a typical week in April 2011 and finally on air traveller arrival and departure observations in the same time period as well as on employee trip characteristics survey, it was made possible to calculate the modal split of all trips from and to the airport for the different categories of trip makers. The above results were expanded to annual basis taking into account overall passenger and employee variations within the last two years (2009–2010). Tables 1 and 2 present the daily modal spilt figures for all trip makers in absolute and % terms and the % share of all different categories on an annual basis.

Table 1 Overall modal split of trip makers to and from the airport

Mode	Vehicle Occupancy	Person trips	MS
Taxi	1,5	1850	17%
Bus	20%	1960	18%
Car	1,6	6920	65%
Total		10730	100%

Table 2 Annual person trips per segment of airport population 2011

Segment	Person trips	% share
Air travellers	4 mil	70%
Escorts	1.15 mil	20%
Employees	0.65 mil	10%
Total	5.8 mil	100%

3 Alternative future links to Thessaloniki airport

3.1 Description of alternative fixed track systems and methodology used

Three main alternative connections between Thessaloniki airport and the city future Public Transport network were examined; (a) a further extension of the Metro at–grade which is under construction, and it will terminate at Mikra station located at the eastern part of Thessaloniki conurbation, some 5 km away from the airport; (b) a segregated Tramway/LRT, which will start from Mikra terminal station and will end at the airport; (c) an elevated Monorail connecting the same two terminal points. For passengers travelling from Thessaloniki city area, all but metro alternatives would require a transfer at the terminal metro station, properly designed to reduce the pertaining inconvenience. The new fixed track corridor under consideration will consist of 5 stations and will have a total length of 5.1 km (Figure 3). Estimations of passenger demand at the intermediate stations of the connection were made by means of a land use inventory, subsequent trip generation calculations and the use of a transport planning model built exclusively for this consideration [4]. The modal operating capacity selected, covers 10 min policy headway, a 25% rail transit share and a directed loading of 1,300 pphpd.
A comparative analysis of the above three systems was performed using the two staged approach of the World Bank [5] as refined later in 2001 [6]. According to this methodology in the first stage non cost attributes of the modal options are considered; most adequate systems will come out from this exercise considering also the demand and supply elements in each specific option. In the second stage the choice of the most suitable mass transit technology will be made in terms of the total costs, namely user costs, operator's cost and community (social) costs. All alternative options were compared against an improved future bus connection starting from the Mikra terminal station.
In this specific case, capital costs among the three alternatives differ significantly as it is the case for the operating costs. The Metro alternative bears high capital and expropriation costs as well as operating costs. Buses on the opposite side are linked with high operating costs and low capital costs. On the other hand metro bears high benefits to its users, especially because there will be no need for transfer from one PT mode to another. LRT and monorail lie in between.

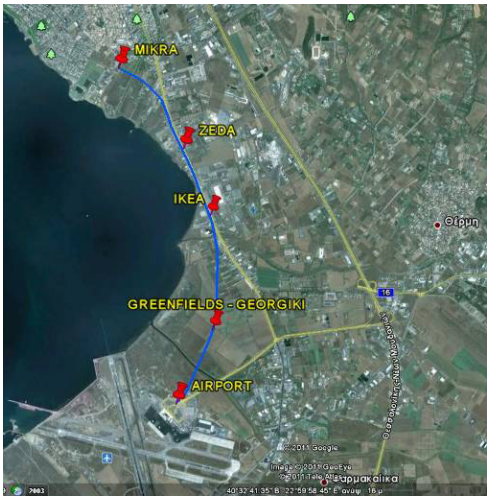


Figure 3 Proposed new Rail–Air Link with intermediate stops

3.2 System, User and Community Costs

Costs examined within the comparative analysis performed, include three main categories, Operator's costs, User costs and Community costs. Operator's costs can be further broken down into capital costs (Rolling Stock, Land, Infrastructure, Electromechanical, Depots, Overheads) and Operating Cost (Staff, Energy, Materials, Outsourcing, Overheads). User costs consist of Time cost (linked to value of time), In–vehicle journey time cost, Transfer penalty costs and Travel variability risk. Finally a mode specific cost (benefit) expressed as Novelty image was also included in the analysis. Community costs consist of Employment costs, Land acquisition costs, and Climate related costs. Table 3 presents in summary the comparison of the 3 fixed track alternatives and the improved bus connection option.

3.3 Stated Choice Experiment

A state choice experiment using a special questionnaire form was conducted in April 2011 at the airport, in order to capture attitudes and preferences of all type of travellers to and from the airport. Specific questions about the three alternative future fixed track systems were included in the questionnaire form. In total 500 valid questionnaires were collected from five discrete segments, namely Greek domestic travellers, Greek international travellers, foreign travellers, escorts and employees. Trip characteristics of travellers were also gathered. A number of different criteria with respect to the most attractive mode to the questioned were set. Table 4 presents the responses of all persons in the sample to those criteria.

Table 3 Main characteristics of alternative Airport Connection options

Scenario		**A**	**B**	**C**	**D**
System		**Metro (3 cars)**	**Tram /LRT**	**Monorail (6 cars)**	**Bus**
Route Length	m	5100	5100	5100	6300
Car Capacity	pax	150	200	34	150
Transit Unit Capacity	pax	450	200	204	150
Max design capacity	pphpd	10800	4000	1300	900
Max speed	km/h	80	70	80	80
Commercial speed	km/h	32	25	40	21–35
In–Vehicle Journey Time	min	10	13	8	15
Scenario		A	B	C	D
Transfer Time (Mikra)	min	0	1	3	3
Walk Time / Egress Time	min	3	3	3	3
Transfer Penalty (Mikra)	min	0	1	3	3
Policy Headway	min	10	10	10	10
Novelty Image	(-) min	1	1	2	0
Minimum Layover Time	min	2,5	2,5	1,5	10
Number of transit units p.h.	no	4	5	2	6
Capital Cost	K€	126,777	78,239	95,567	3,600
Operating Cost	K€	4,200	3,300	4,000	2,200
Land Cost	K€	4,000	2,900	525	0

Table 4 Mode choice criteria per user group category

Criterion	Air Travellers	Escorts	Employees
Duration of the trip	92.6%	92.0%	98.0%
Cost of the trip	90.0%	91.0%	93.0%
Minimization of transits	89.6%	88.0%	91.0%
Comfort	82.0%	79.0%	87.0%
Reliability	95.6%	93.0%	97.0%

By using the related behavioural characteristics obtained from the state choice experiment per scenario examined, it was made possible to construct 3 transport planning models, one per alternative. In addition two more models were build, one for the existing bus connection (Do_Min) and one for an improved bus connection, starting from MIKRA terminal station every 10 min (Do_Min_B). The outputs of the model runs for horizon 2016 in terms of peak hour maximum passenger load per direction for the heaviest sections are shown in Table 5. From these results it can be seen that the Metro option attracts the highest passenger load, whilst the monorail comes second. The improved future bus connection comes very close to the monorail option.

Table 5 Projected peak hour max. Passenger load per Scenario (2016)

Scenario	Direction	Max Passenger Load ph	Segment
A	From Airport	976	ZEDA–MIKRA
	To Airport	617	MIKRA–ZEDA
B	From Airport	456	ZEDA–MIKRA
	To Airport	273	MIKRA–ZEDA
C	From Airport	662	ZEDA–MIKRA
	To Airport	380	MIKRA–ZEDA
Do_Min	From Airport	63	KRIKELA–25HS MARTIOY
	To Airport	235	FALIRO–SXOLI TIFLON
Do_Min_B	From Airport	657	IKEA–SASTH–VIAMIL
	To Airport	169	EMPORIKO KENDRO–POLYFOTA

4 Comparative Analysis results and Conclusions

The results of the comparative analysis performed among the three fixed track alternatives and the future improved bus connection in terms of total implementation and operating costs are shown in Table 6. It should be stressed that the bus option refers to a link from Mikra terminal station to the airport and vice versa and not to a direct link from/to Thessaloniki city centre.

All costs were annualised in order to allow for a direct comparison. Transit investments assumed to be made by a 30 year loan with an interest rate of 8%. Annual payments cover both principal and interest. Targeted passenger demand is achieved in 2030, whilst in 2016 the lower demand is satisfied at a reduced cost by longer headways. For the metro option, land expropriations are necessary whilst for the tram system the respective needs are smaller. The monorail does not require any expropriations. In addition Tram/LRT and monorail require space for a depot which depends on the 'future' number of transit units. There is no such a need for the metro since a depot will be available from the main metro line. Regarding ope-

rating cost of each system a detailed cost calculation was made. The same figure applies to energy consumption, spare parts needs and other outsourcing costs. Finally, an average farebox revenue of 2€ for rail alternatives, and 1€ for bus, was assumed as a 100% operating cost recovery.

The summary findings presented in Table 6 indicate that the alternatives examined do not differ significantly in terms of total cost. The bus, as expected is the cheapest one, but it does not secure in the future an adequate level of service. Furthermore, it is more vulnerable to congestion conditions as well as to unexpected events. Monorail seems to be the cheapest option among the fixed track ones and most easy to implement. However, it is lacking potential for extension, something that may be proven necessary given the development in the areas beyond the airport. The Tram/LRT is the least preferred option, given that it is the most expensive after the Metro and at the same time it is associated with many other disadvantages such as need for land space, interaction with traffic and need for a new depot. The Metro on the other hand is associated with many advantages but at the same time is the most expensive and time consuming with a very high capacity reserve (low utilization rate). The final dimension needed to be taken into account is the potential for development in the area along the fixed track and the possible gains in land value. Such gains can partially finance implementation and operation of the air–rail link. This is not possible in case of maintaining the bus connection.

Table 6 Total cost per alternative mode

Mass Transit Technology	Metro	Tram/ LRT	Mono–rail	Do_Min_B (Bus)
User Costs				
In Vehicle Journey Time Costs	8.900	11.360	7.380	10.870
Transfer Penalty Costs ('Mikra' terminal)	0	1.142	3.125	3.125
Cost of Travel Time Variability (Risk) approaching the Airport	0	0	0	3.588
Novelty Image Cost (benefit)	-1.168	-1.168	-2.337	0
Sum User Costs	7.732	11.334	8.168	17.583
Operator's Costs				
Capital Costs (8%, 30y.)	11.261	6.950	8.489	320
Operating Costs	4.200	3.300	4.000	2.200
Sum Operators' Costs	15.461	10.250	12.489	2.520
Community Costs				
Employment Costs (benefits)	-346	-302	-317	-223
Land Acquisition Costs (4%, 30y.)	231	168	30	0
Climate Cost (benefit)	0	0	-70	0
Sum Community Costs	-115	-134	-357	-223
SUM Total Costs (000) (annualized 2011 prices)	23.078	21.450	20.300	19.880

References

[1] Thessaloniki Public Transport Authority, Connection of Thessaloniki International 'Macedonia' Airport with future fixed track rapid system network of Thessaloniki, Project co-funded by the EU CIVITAS CATALIST Programme Feasibility Report, Greece, 2011

[2] Thessaloniki Public Transport Authority, Connection of Thessaloniki International 'Macedonia' Airport with future fixed track rapid system network of Thessaloniki, Project co-funded by the EU CIVITAS CATALIST Programme , Stated Choice Survey Report, Greece, June 2011

[3] Athens International Airport, AIA 2003 Passenger and Employee Survey, Greece, 2004

[4] Thessaloniki Public Transport Authority, Greater Thessaloniki Area Transport Planning Model for the Metro extension to Kalamaria, Technical Report, 2011

[5] Armstrong-Wright Alan, Urban transit systems: Guidelines for examining options World Bank Volume/ Edition 52, Washington D.C.1986.

[6] Parajuli P., Wirasinghe S., A Line Haul Transit Technology Selection Model, Transportation Planning & Technology, Vol 24, 2001 pp. 271-308